Objective Detection, Evaluation and Countermeasures for In-flight Depression

Completed Technology Project (2007 - 2011)

Project Introduction

Spaceflight environmental and psychological stressors can significantly disrupt one's ability to function effectively and efficiently, and the associated performance deficits can seriously jeopardize space missions. Mission success can be jeopardized either directly, from the potentially life threatening consequences of lapses in performance, or indirectly, by adding to the workload and stress of other crewmembers. The substantial likelihood and potentially serious consequences of neurobehavioral conditions during spaceflight, such as depression, helps explain why the Bioastronautics Roadmap Risk of human performance failure due to neurobehavioral problems is a high priority risk for all mission types (International Space Station (ISS), Moon, Mars). For depression, a variety of therapies are already available, including preventative measures, medications, and psychological consultations with ground-crews. However, current methods to decide whether a therapy needs to be used rely heavily on subjective self-report. The biological basis of mood disorders suggests that neural biomarkers may be able to provide a more objective method for assessing depression and potential performance deficits. The goal of this proposal was to identify neural biomarkers sensitive to, and specific for both detecting depression and assessment of depression severity. In this project, we identified multiple putative brain biomarkers of both the presence/absence of depression as well as of depression severity. These included both structural alterations in regional cerebral gray and white matter, as well as changes in brain function. This work strongly supports the feasibility of using brain measures to more objectively detect and assess depression. While these findings were promising, there is currently no reliable way to monitor brain state or function in spaceflight. Thus, the second important component of our project was development, evaluation, and validation of a novel and flight-capable neuroimaging technology: near-infrared neuromonitoring (NIN). We first developed a novel, noninvasive NINscan 2a device, and then sought to test it in suitable analog settings. A parabolic flight test demonstrated the device's performance in microgravity, and also identified differences in cerebral versus systemic hemodynamic response to changing gravitational fields. The NINscan 2a prototype was also tested during three separate treks to the peak of Mt. Kilimanjaro. These treks demonstrated (1) the system's robustness to remote and extreme environments, (2) its usability by non-experts, and (3) its sensitivity to brain tissue by identifying cerebral hemodynamic changes associated with both altitude and acute mountain sickness induced by hypoxia and hypobaria.

In a head-down tilt analog study, we further demonstrated that the NIN technology is only minimally affected by the headward fluid shifts associated with microgravity. Since the NINscan 2a prototype was found to be only modestly sensitive to the small signals associated with brain function, we therefore began development of a second and third new NINscan prototype (3a and TD). Both were designed for significantly improved sensitivity and flexibility. The most recent, NINscan TD, included a novel embedded

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Table of Contents

microcontroller that could serve as the foundation for developing a whole-head NIN imaging instrument. In sum, we identified a number of putative brain-based biomarkers for more objectively detecting depression and assessing its severity. We simultaneously developed and tested novel prototype devices for brain monitoring, including multiple independent tests in analog environments, and demonstration of NIN sensitivity to cerebral hemodynamics. Jointly, these efforts substantially increase the readiness level of using brain monitoring technologies to more objectively assess in-flight depression and perform in-flight brain assessment in general.

Anticipated Benefits

Our research activities are expected to have two primary impacts. First, identification of brain-based biomarkers for depression would be useful for the millions of individuals suffering from depression on Earth, by providing a more objective and potentially less expensive and more readily accessible method for evaluating depression. Such a biologically based assessment method could also be used to more objectively track responses to various forms of treatment, including drugs or cognitive/behavior therapy.

Second, our technology development efforts have moved the technology readiness level (TRL) of near-infrared neuroimaging to TRL 6, based on our multiple prototypes and five separate analog tests, conducted in parabolic flight, extreme (remote and high altitude) environments, and a head-down tilt fluidic analog of microgravity. Our focus on lightweight, inexpensive and unobtrusive NIN technology will enable brain imaging and monitoring not only during spaceflight, but also in a variety of novel Earth-based contexts including in-office neuroimaging, home-based monitoring (e.g., of sleep apnea), ambulatory monitoring (e.g., of syncope) in rural areas or under-served communities, and first-responder settings (e.g., sporting events, accident scenes, or cases of suspected stroke). Mobile neuromonitoring and neuroimaging is therefore expected to open up entirely new domains of clinical research and practice.

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Organization:

National Space Biomedical Research Institute (NSBRI)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

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Co-Investigators:

James Cartreine Nee Carter
Quan Zhang
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Albert Yeung
Gregory Feldman

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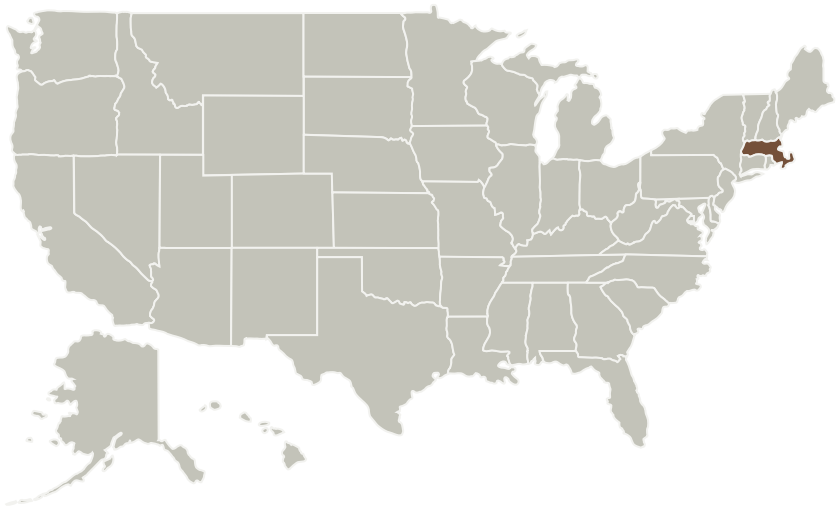
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
National Space Biomedical Research Institute(NSBRI)	Lead Organization	Industry	Houston, Texas
Brigham And Women's Hospital, Inc.	Supporting Organization	Industry	Boston, Massachusetts
Massachusetts General Hospital	Supporting Organization	Industry	Charlestown, Massachusetts

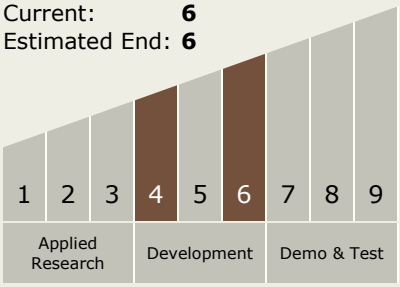
Primary U.S. Work Locations
Massachusetts

Project Transitions

October 2007: Project Start

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - TX06.3 Human Health and Performance
    - TX06.3.3 Behavioral Health and Performance

Target Destinations

The Moon, Mars

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October 2011: Closed out

Closeout Summary: In the past year, we made significant progress in three primary areas: experimental, computational, and technology development. On the experimental front we completed our neuroimaging study of depression. The goal was to identify more objective brain biomarkers for detecting depression and for assessing depression severity. We recruited 20 depressed individuals (age 30-60, Bachelor's degree or higher, un-medicated) along with 19 matched healthy controls and collected data on multiple structural and functional MRI (magnetic resonance imaging) and NIN measures. Measures were e xamined for (1) their ability to detect depression (Aim 1a), and (2) their ability to assess depression severity (Aim 1b). We i dentified multiple putative brain biomarkers for both detection and assessment, including both structural and functional brai n measures. Manuscripts are in preparation. We also completed data analysis for two analog tests. In our head-down tilt (H DT) study, headward fluid shifts were hypothesized to adversely affect NIN sensitivity while performing our depression stud y's working memory tasks. Modest sensitivity loss was observed during acute -6 degree HDT relative to +45 degree head u p tilt, but similar functional activation was still detected by NIN. This demonstrated the sensitivity of NIN to brain function i n these tasks (Aim 3), as well as the robustness of NIN to HDT. In our Aug 2010 Kilimanjaro analog study, we examined da ta from 6 hikers at 6 different altitudes performing Valsalva and Mueller maneuvers. We observed significant increases in ce rebral blood volume (CBV) with altitude, but significant decreases in CBV in individuals affected by acute mountain sicknes s. This demonstrated (1) the ability to perform NIN experiments monitoring cerebral physiology in an extreme environmen t, (2) the sensitivity of NINscan 2a to cerebral hemodynamics (Aim 3), and (3) provided preliminary evidence that cerebral edema and mild increases in intracranial pressure are involved in acute mountain sickness. On the computational front, we completed analysis of our simulations modeling the distribution of photons migrating through the head. This generated the most detailed maps to date of NIN sensitivity to brain tissue and also supports Aim 3. Sensitivity was found to be more spat ially variable than previously assumed, but we identified ways to design probes and devices to compensate for such sensitiv ity differences. Two manuscripts describing the results of this work are currently under review. On the technology developm ent front, we completed NINscan 3a, a next-generation device that is considerably more sensitive and capable than NINsca n 2a. We also completed NINscan TD, a microcontroller-based design that provides even more flexibility (including light and detector gain controls) as well as a proof of concept design for scaling to whole-head neuroimaging. These efforts strongly s upport the goal of developing technologies suitable for brain imaging in spaceflight (Aim 2).

Stories

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/44871)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/44866)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/44865)

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(https://techport.nasa.gov/file/44867)

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(https://techport.nasa.gov/file/44878)

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Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/44876)

Project Website:

https://taskbook.nasaprs.com